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Review

A Critical Review of Blockchain Acceptance Models—Blockchain Technology Adoption Frameworks and Applications

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Abstract: Blockchain is a promising breakthrough technology that is highly applicable in manifold sectors. The adoption of blockchain technology is accompanied by a range of issues and challenges that make its implementation complicated. To facilitate the successful implementation of blockchain technology, several blockchain adoption frameworks have been developed. However, selecting the appropriate framework based on the conformity of its features with the business sector may be challenging for decision-makers. This study aims to provide a systematic literature review to introduce the adoption frameworks that are most used to assess blockchain adoption and realize business sectors that these models have been applied. Thus, the blockchain adoption models in 56 articles are reviewed and the results of the studies are summarized by categorizing the articles into five main sections including supply chain, industries, financial sector, cryptocurrencies, and other articles (excluded from the former fields). The findings of the study show that the models based on the technology acceptance model (TAM), technology–organization–environment (TOE), and new conceptual frameworks were the focus of the majority of selected articles. Most of the articles have focused on blockchain adoption in different industry fields and supply chain areas.

Keywords: blockchain technology; acceptance model; adoption model; blockchain adoption; blockchain acceptance; blockchain acceptance model; blockchain acceptance framework; narrative review

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1. Introduction

Blockchain (BC) was initially introduced in 2008 by Nakamoto, and it is currently the focus area of many businesses because of its role in the transformation of operational processes. According to the main characteristics of blockchain technology including traceability, transparency, smart contracts, and security, this technology is not only used for its main application as a cryptocurrency but is also applicable in manifold areas such as government elections, healthcare, logistics, identity management, supply chain, etc. [1].

Each block in the structure of the blockchain is made of a new set of transactions. All the transactions that have occurred in the network are recorded by the blockchain through applying a distributed database and the collaborated nodes among them. The blocks are performed by these nodes which are known as miners. Thus, the problems happening due to the trust of a centralized party can be addressed successfully using this system, and this technology can bring security to the transactions as it employs a distributed way that is not related to any trusted party. These features bring other qualities such as decentralization, trust, and immutability to blockchain technology [2].

The popularity of this technology has brought different frameworks and platforms of blockchain for more than a decade. These different infrastructures developed the ap-

plication of blockchain by addressing manifold issues in different areas such as the Internet of Things (IoT), cryptocurrencies, and smart contracts. The main frameworks are shown in Figure 1 and are discussed in the following sections.

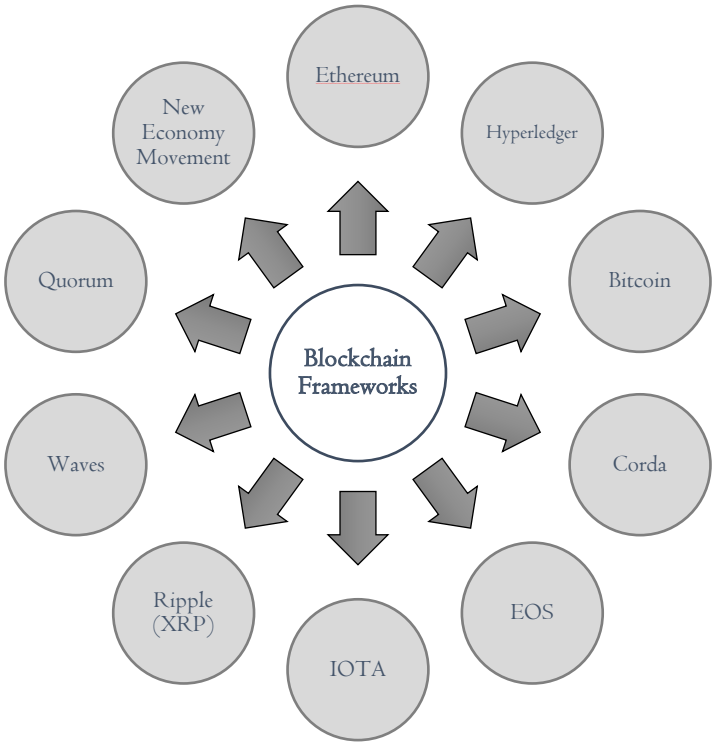

Figure 1. Blockchain frameworks.

Ethereum, as an open-source platform, provides the likelihood of developing decentralized services online, and on the decentralized applications (DApps) operating based on smart contracts. This platform includes four main components including Ethereum virtual machine (EVM), smart contracts, decentralized applications (DApps), and finally the parameters to examine the framework performance. Another platform supported by IBM and Linux Foundation is recognized as Hyperledger. This framework is applicable to advance cross-industry blockchain technologies. Additionally, Bitcoin, which is the most popular and the first internationally recognized cryptocurrency framework, was formed in 2009 [3,4]. Corda platform is another framework that was introduced for two main applications including legal contracts and data sharing between mutually trusting companies. This also brings the possibility of manifold applications based on the interoperating on a single network [5].

EOS is also another blockchain framework that is applicable for the private and public sectors. This platform can address special business needs such as industry-leading speeds, secure application processing, and role-based security permissions [3]. The next framework is the IoT applications (IOTA) platform, which was introduced initially in 2016 for IoT applications as a new transaction settlement. Transactions can be performed through a new peer-to-peer method recognized as tangle by using this platform [6]. This system, unlike other platforms, does not possess the structure of the traditional blockchain. Ripple (XRP) platform is also another framework that was introduced formerly as OpenCoin Ripple, which is used for exchange and payment networks. The network (RippleNet) is on top of a ledger database known as XRP Ledger, which is a distributed database. This framework aims to provide a connection between banks, digital asset exchanges, and the providers of payments, which makes global payments cost-efficient and faster.

In addition to the discussed platforms, the Waves framework is a decentralized and open platform that provides to build applications through the employment of new cryptocurrencies. The noted unique quality of this blockchain platform can help application developers to build all applications created based on the blockchain using a software platform including several utilities and tools. Furthermore, the main issues of using distributed registry and small contracts applications in the financial sector were addressed by using the Quorum blockchain framework. This platform was introduced by JP Morgan to generate the volumes of institutional transactions. The restrictions to access the transaction history are possible using the Quorum framework with the system transparency. The final platform is known as the new economy movement (NEM or XEM) and was developed to obtain high speed and scalability. This private platform includes a proof-of-concept (POI) mechanism that is a revolutionary consensus system that can add a block to the blockchain and is utilized to assess the important network participants [3].

The blockchain concepts and its applications as well as common frameworks are discussed above. According to the application of BC technology in different areas, the main contribution of this study is to investigate the adoption of blockchain in different sectors, which helps researchers to gain a comprehensive list of the models that can be applied for BC acceptance. Furthermore, in this paper, the adoption models are listed based on the fields of study which can identify a lack of studied sectors as well.

In the following sections, first, the main acceptance models and the importance of assessing blockchain adoption will be summarized. Next, the articles that studied blockchain adoption in different areas will be reviewed (in the methodology section) to reach "the models utilized in the blockchain adoption" and "the sectors/fields of studies" as the research questions. Finally, the results will be discussed to clarify the application of blockchain in different sectors.

2. Acceptance Models

After developing and introducing new technologies, it is important to consider the adoption rate of the platform utilizing the users' acceptance to gain more development [7]. The acceptance rate helps decision-makers in the development step to consider the problems that users may face through applying technology. This factor is illustrated as an important antagonism to the term refusal, which also means the decision to apply a technology/innovation positively [8].

In other words, if it is possible for researchers to recognize whether people accept new specific technology or not as well as the reasons behind that; these can help them to acquire better results in the innovation process [9,10]. These studies, which are known as adoption or acceptance models, also encourage them to obtain better mechanisms to evaluate and predict the responses. These frameworks are used in a variety of fields such as education, supply chain, voting, transportation modes, computer users, and even blood donating [10,11]. Different frameworks have been developed to illustrate the users' adoption based on considering diverse factors in the models. The most common models are discussed in the following sections.

2.1. Theory of Reasoned Action (TRA)

Although first-time TRA was developed by Fishbein and Ajzen [12] for the studies on the psychological and sociological fields, nowadays, it is utilized to study the behavior of the people when they use IT. Three main components that are used in this model are as the following:

- Attitudes which include favorableness or favorableness of the feelings of individuals for an attitude;
- Social norms which are about people's social influence [11,13];
- Intentions including whether individuals decide to perform a behavior or this factor is influenced by the former ones [14,15].

The behavior of the individuals can be considered as systematic and volitional. In addition to these components, for testing and evaluating the TRA model, three boundary factors are defined including the stability of intention over time, volitional control, and the intention measurement considering context, target, time, specificity, and auction terms. Although this model also employs methods such as time horizon and generality to enhance the robustness between attitude and the corresponding intention, some terms are not addressed yet in this framework. For example, there is still a lack in the role of habit, the moral factors, and misunderstanding through a survey, the cognitive deliberation, and the issues due to the usage voluntariness for the validation process [11].

2.2. Theory of Planned Behavior (TPB)

This adoption framework was initially introduced by Ajzen [16] through developing the TRA. In this model, perceived behavioral control (PBC) is added to the traditional TRA factors. The perceived significance of the skills, opportunities, and resources as well as the availability of them are used to determine the PBC and gain the outcomes [14].

By using PBC, TPB is able to consider and compose the people's actions that are not under volitional control and realistic limitations as well as obtaining a self-efficacy type factor. However, in both TRA and TPB models, the people's behavior is influenced by the behavioral intention (BI) of individuals [11].

2.3. Technology Acceptance Model (TAM)

Derived from the TRA framework, this model was initially developed by Davis [17,18] to address the uncertain status of psychometric and theoretical in TRA through eliminating subjective norms. The TAM framework is one of the most widely cited adoption frameworks and includes the perceived ease of use and perceived usefulness as the main factors [7]. Although the impact of attitude toward technology use is another vital factor in applying the TAM framework (Figure 2), not only does TAM contain BI, but the impact of two vital beliefs (perceived ease of use and perceived usefulness) is also considered on the users' attitudes, which are examined as the favorableness and unfavourableness toward the system [11].

In this model, the influence of perceived ease of use and perceived usefulness on the attitude and BI are direct and indirect, respectively, and the perceived ease of use impacts the perceived usefulness directly. This model also considers external variables such as system characteristics, user training, user participation in design, etc., as is shown in Figure 2.

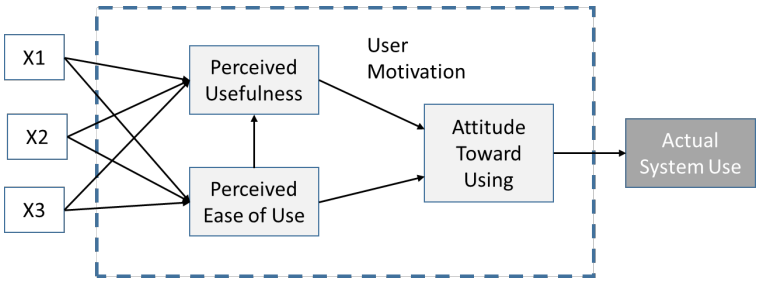

Figure 2. Original TAM [17].

2.4. Extension of TAM (ETAM)

Adding new factors to the traditional TAM and developing the extended models helps to address the limitations of the original model, which can improve the adoption models' capabilities. These factors are added to enhance the specificity as well as explanatory power of normal TAM. Thus, the predictive power of perceived usefulness and social influence can be improved by adding these factors [14]. There are two main studies on ETAM that are mentioned in the following:

The first one is known as TAM2 that is based on the antecedent of perceived usefulness and BI. There are two main constructs added to TAM including social influence (voluntariness, subject norms, and image), and cognitive (output quality, job relevance, and result demonstrability). These can help to enhance the predictive power of perceived usefulness [19,20].

The second one considers additional constructs impacting the perceived ease of use which are two main categories known as anchors and adjustments. The anchors are the general beliefs about the usage of computer systems, and the adjustments are the factors about the basis of direct experience of a given technology such as computer playfulness and computer anxiety [11,21]. Different authors have provided different extended TAM models in their studies. One of these models used by [22] to study the adoption in the aviation industry is shown in Figure 3. The modified framework is also described in the next sections.

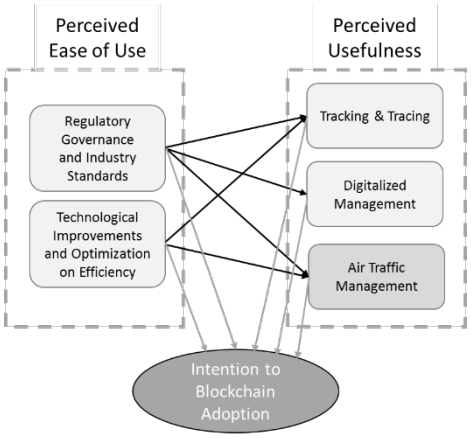

Figure 3. Extended TAM [22].

2.5. Diffusion of Innovation (DOI)

The diffusion of innovation includes different steps considering five important factors as effective variables in the acceptance of innovation in the characteristics of the innovation step, including compatibility, observability, complexity, trial ability, and relative advantage [14,23]. In the next step, known as the adopter characteristics step, the categories are considered as innovators, early adopters, late majority, early majority, and laggards. Finally, the innovation-decision step includes implementation, knowledge, persuasion, confirmation, and decision over time and through communication channels' set between the members of similar social systems [24]. This model also introduces four factors to determine a diverse range of innovations that can influence the extension of a new idea [25]. These factors are channels of communication, time, innovation, or social system.

The DOI framework can address the organizational, individual, and even global levels of adoption using a theoretical foundation. This acceptance model employs the integration of the main components including the innovation-decision process, characteristics of an innovation, and adopter characteristics. In addition, the DOI addresses the environmental factors, the characteristics of the system, and the organizational attributes. It is also less focused on the explanatory analysis. Therefore, this method has also demonstrated less power in the prediction of outcomes practically compared to the other acceptance frameworks [11].

2.6. Unified Theory of Acceptance and Use of Technology (UTAUT)

This framework was initially developed by Venkatesh [26] by using a combination of eight models including TRA, TPB, TAM, DOI, and extended TAM as well as the motivational model, social cognitive theory, and model of PC utilization. This model compares these frameworks to examine similarities and differences. Four constructs are derived as the result of this process as facilitating conditions, social influences, efforts, and performance expectancies. However, in addition to those constructs, age, gender, voluntariness of use, and experience were utilized as the moderating variables in this model [14].

2.7. Task Technology Fit Model (TTF)

This model examines whether the capabilities of new technology or innovation can cover the tasks that must be performed. This framework is based on eight vital constructs including systems reliability, ease of training/use, production timeliness, quality, authorization, compatibility, users' relationship, and capability [27,28].

2.8. Technology–Organization–Environment (TOE)

This model was initially described in the processes of technological innovation by Tornatzky and Fleischer [29]. This is about the whole innovation process ranging from the development by the entrepreneurs or engineers to its adoption by users. TOE, however, includes one section of this process about the impact of the firm context on the innovation implementation and its acceptance. This framework considers three main contexts (technological, environmental, and organizational) to explain how the elements of a firm impact the adoption decisions at an organizational level [30].

3. Why Is Blockchain Acceptance Analysis Important?

The main adoption models were reviewed in the previous section; however, it is important to realize the reason that these studies are vital in the BC field. Blockchain, as a promising breakthrough technology, possesses diverse applications in a wide range of areas such as industries, banking, healthcare, etc. The special features of this technology make it essential to adopt for companies. However, possible risks and challenges during the implementation of the technology can overshadow the success of the process as well [31]. For example, the lack of consumer awareness and the barriers surrounding it are among the challenges that need to be considered as these factors can affect the users' direct experience of the technology [32].

To examine the results of different challenges that blockchain projects may face, the blockchain-based projects in China between 2014 and 2017 are taken as examples. The statistics show that even though an increase was reported in the first years (2014–2016), the number of projects decreased from 834 in 2016 to 527 in 2017 [33]. That is the reason why studies on the adoption and satisfaction of the users are vital to determine the significant elements affecting the implementation of the blockchain and address the issues that can address acceptance challenges. Thus, the adoption and acceptance models are reviewed in this study to determine the significant factors, challenges, and barriers in blockchain technology in different sectors based on the research questions provided in the methodology design step. For this, the next section provides a systematic literature review to determine the acceptance models that are frequently used in the adoption of blockchain in different fields and their significant factors.

4. Research Methods

This section aims to provide a comprehensive systematic literature review by summarizing the studies on the acceptance models used to examine blockchain adoption due to the importance of investigating this subject as a new technology. For this, the main objective of this paper is to answer the following research questions:

- What are the adoption models used to assess blockchain acceptance?

- What are sectors that have used blockchain adoption for the assessment?

First, six keywords were selected as the search items including "blockchain adoption", "blockchain adoption models", "blockchain adoption frameworks", "blockchain acceptance", "blockchain acceptance models", and "blockchain acceptance frameworks" in the "ScienceDirect" database, conducted on 25 December 2021, limiting the search to the papers that have been published between 2008 and 2022. The first group of articles was chosen based on screening their titles, abstracts, and keywords. Then, the full text of the chosen papers was assessed to find the eligible papers for this study. In addition, a manual search and back-and-forth citation tracking were conducted on the Google Scholar database and the eligible articles were added to previous ones. Then, 56 articles, whether Scopus-indexed or not, were chosen for the next step.

In the next step, the articles were categorized into five different groups based on the field of the study and the area that blockchain adoption was used to analyze, including supply chains, different industries, financial sectors, cryptocurrencies, and others. It is preferred to discuss the articles that have focused on the cryptocurrencies as the most important application of blockchain in a separated section, and also the last group of articles that is named as others is provided based on the studies out of the formerly listed areas and the general ones without focusing on any specified area. Finally, constructs of the adoption models as well as the important results were obtained. This process is shown simply in Figure 4, and the papers are discussed in the following sub-sections.

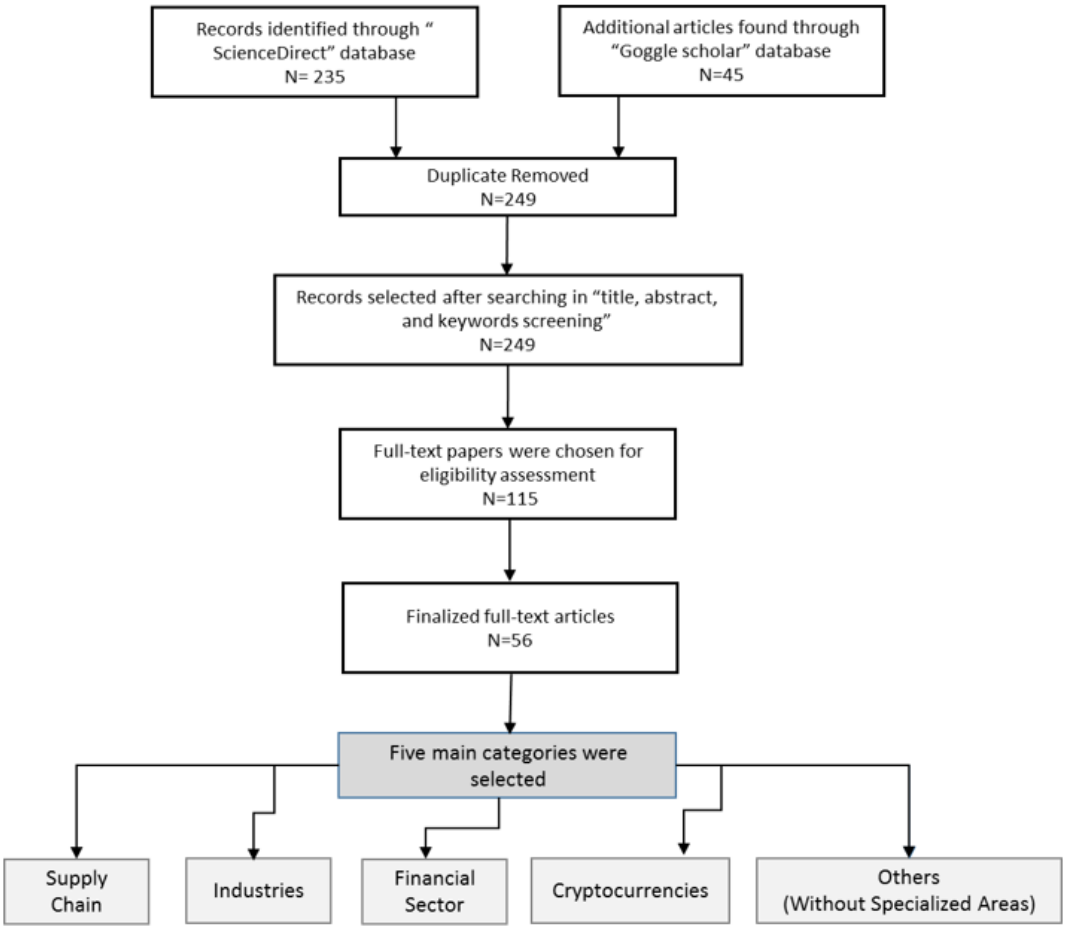
Records identified through " ScienceDirect" database N= 235
Additional articles found through "Goggle scholar" database N=45
Duplicate Removed N=249
Records selected after searching in "title, abstract, and keywords screening" N=249
Full-text papers were chosen for eligibility assessment N=115
Finalized full-text articles N=56
Five main categories were selected
Supply Chain
Industries
Financial Sector
Cryptocurrencies
Others (Without Specialized Areas)

Figure 4. Research methods; step-by-step.

5. Blockchain Adoption in Supply Chain

Different studies were conducted on the adoption of BC in the supply chain. These studies used manifold acceptance frameworks such as TAM, UTAUT, TOE as well as the integration of the models, extended frameworks, and also new specific models that have been used in some studies.

Kamble et al. [34] has referred to an integrated model using the TAM, TRI, and TPB frameworks to study blockchain adoption in India. TAM constructs were used to investigate the perceptions of the end-users on the utility and ease of use, by considering perceived usefulness and perceived ease of use as the model's variables. Various variables were also considered including actual use, intention to use, behavioral attitudes, subjective norms, and perceived behavior control that stem from control factors of the observation in the TPB theory. Finally, the general beliefs of individuals about technology, including innovativeness ("the aptitudes towards being a leader in the technology area"), discomfort (stems from lack of control), insecurity (stems from the suspicion feeling about the incapability of the innovation), and optimism or positive view, are studied to gain the constructs of the TRI model. The results of this study are summarized in Table 1.

In addition, in the supply chain area, two different studies were extracted based on the employment of the UTAUT model for blockchain acceptance investigation. First, Queiroz and Wamba [35] developed their model using the information adopted from their provided literature study and TAM and used the information to gain an altered/extended UTAUT model. They explained performance expectancy as "the degree to which an individual believes that using the system will help him or her to attain gains in job performance". They also considered other factors such as social influence to present "the degree to which an individual perceives that important other believe he or she should use the new system", facilitating conditions which are "the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system". Blockchain transparency was also defined in their paper as "the models through which an organization communicates and reports its action to its relationships across the supply chain network, to support the visibility of the operations at all levels". Trust among supply chain stakeholders was found as another construct of their model to identify "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party". The final variable was the behavioral intention (BI) which considers "the degree to which a person has formulated conscious plans to perform some specified future behavior". In the study, the adoption of blockchain in supply chain and logistics in the USA and India is compared, and it was realized that the positive impact of performance expectancy on behavioral intention is a motive behind blockchain adoption.

Additionally, Wong et al. [36] have listed some similar factors as the former paper as performance expectancy, facilitating condition, and trust. However, they also used effort expectancy as "the degree of ease associated with consumers' use of technology", technology readiness as "the people's propensity to embrace and use new technologies for accomplishing goals in home life or at work", technology affinity as "an individual's propensity for active engagement or avoidance with technology to cope with technology; and is considered a personal resource to successfully cope with technology", and finally, they considered regulatory support among the most important challenges in bitcoin adoption. The results are shown in Table 1.

The TOE model, as another main framework, was applied in different articles to discuss blockchain acceptance in the supply chain. Kouhizadeh et al. [37] used a TOE framework to identify the adoption barriers together with force field theory to examine the importance of organizational change and transformation. In this research, two groups of people including academics and practitioners were under study. They listed the TOE factors as described in Table 1. However, the TOE sub-categories can change in different studies. For example, in another study, TOE was integrated into TAM using a machine

learning approach by Kamble et al. [38] to identify the significant factors of BC acceptance in the supply chain. The TAM factors were the perceived usefulness and perceived ease of use, and the TOE factors were as the follows:

- Technological constructs: perceived financial benefits, technical know-how, complexity, relative advantage, compatibility, and information security.
- Organizational constructs: training and education as well as top management support.
- Environmental constructs: competitive pressure and partner readiness.

Additionally, another example is a framework based on the three general constructs of TOE conducted by Lanzini et al. [39]. They have listed their sub-categories as organizational including top management enthusiasm, people's readiness, process readiness, technology readiness, and top management support; and technological constructs such as cost, governance, observability, perceived compatibility, perceived ease-of-use, perceived usefulness, privacy, and trial ability. Environmental factors in this study were customers' influence, competitive pressure, cooperation with information and communications technology (ICT) providers, government support, trading partners' readiness, and regulatory status. This model was used to determine the most important construct. Kouhizadeh et al. [37] realized that the security challenges, the negative perception toward technology, and technology immaturity have demonstrated the most influence as the technological contexts. The significant organizational variables were listed as shortage of management commitment and support, knowledge, and expertise together with hesitation that may be faced in case of converting to new systems. Academics identified cultural differences of supply chain partners as the effective factor between the supply chain barriers. However, practitioners introduced the lack of customer awareness and tendency as an important factor. For external barriers, academics found a lack of industry involvement, external stakeholder involvement, and rewards and incentives as the most significant barriers. However, a lack of industry involvement, external stakeholder involvement, and government policies were listed as critical factors.

A TOE model was used by Suwanposri et al. [40] by introducing new constructs including (1) operational efficiency (technological), (2) suitable application (organizational), (3) supportive governmental regulations and policies (environmental), and (4) stakeholder cooperation (environmental). Data integrity and data security were other factors of the technological group. Organizational readiness, employee readiness, and top management support were used as the organizational ones. Finally, the network effect was considered as the environmental factor.

In addition to the main frameworks, some researchers prefer to focus on the new conceptual/theoretical frameworks in this field. A new conceptual model was used in 2020 to investigate adoption in the supply chain in India and USA. In this study, Wamba et al. [41] considered the trading partner relationship as a factor that is about a business relationship involving two or more organizations and customers. They also used knowledge sharing, transparency of the supply chain and blockchain, and supply chain performance variables in their model. According to their results, knowledge sharing and trading partner pressure are important factors in blockchain adoption.

Another modified framework was used by Aslam et al. [42]. Their framework was based on the relationship between the supply chain management (SCM) practices and blockchain features as well as the impact of SCM practices on operational performance. The blockchain factors were studied as different variables such as transparency, cybersecurity, and reliability. The SCM practices were listed as the factors such as the close partnership with the supplier and the customer, and third-party logistics, subcontracting, and outsourcing. They also focused on operational performances such as reduced lead time and flexibility. The authors identified the positive relationship between supply chain management and operational performance as the result.

Among new frameworks, some were conducted similar to the TOE frameworks with the main dimensions that were discussed before and based on the models with different main and sub-categories in their studies. For example, a decision-aid model was used by Karuppiah et al. [43] by considering 40 prominent variables under six main challenges in blockchain adoption including organizational, facial, technological, privacy and security, regulatory, and societal challenges. To hit this target, they investigated different sub-categories in six main groups of challenges. The organizational category included challenges such as a lack of knowledge about BC technology, blockchain framework development, new organizational policies, skilled workers, and management support. The second group as facial challenges considered the factors such as the high initial cost of implementation, the expensive cost for research and development, and the cost of resources. Technological aspects were variables such as low transaction scalability, high latency, high power requirement, immutability, difficulty in data integration, single point of failure, and also the quality of data. Privacy and security were considered as another challenge in this study, covering challenges such as inefficient data security protocol, lack of privacy, vulnerability to cyber attacks, lack of trust, anonymity, loss of private key, double spending, and false data injection. Regulatory in this paper was also about factors such as lack of government support, and taxation issues. Finally, societal challenges include misconceptions about blockchain technology. In this study, the variables were weighted and ranked to obtain the most significant challenges. According to the weights, a lack of BC knowledge, non-existence of universal regulatory binding, and new organizational policies ranked as the first three top positions with 0.0283, 0.0276, and 0.0274 reported weights, respectively. The authors also identified the cause and effect parameters. Other factors of the six constructs are listed in Table 1.

Using integrated approaches was the main focus area of the study conducted in 2020 by Yadav et al. [44] based on an ISM-DEMATEL (decision-making trial and evaluation laboratory) approach for modeling the constructs and investigating adoption in the agricultural supply chain in India. A diverse range of barriers has been considered in this study by applying the literature together with the experts' opinions. Some of the barriers included the complexity of blockchain-based system design, huge resource and initial capital requirement, security and privacy concerns, and agro-stakeholder resistance to blockchain culture. Other factors are listed in Table 1. Finally, a lack of trust among agro-stakeholders and lack of government regulation were identified as the most significant factors. Sunmola et al. [45] have conducted a similar work by using the variables reached from systematic literature to study blockchain adoption in the digital transformation of the supply chain. They finalized eight variables as the factors of their framework and also used case studies to gain the results that are shown in Table 1. Sahebi et al. [46] also examined the list of barriers including 14 factors based on the literature, as well as experts from different fields such as humanitarian experts, academics, and cryptocurrency experts. Then, they analyzed the factors using the integration of the best-worst method (BWM) to the fuzzy Delphi method and finalized the number of accepted variables to nine factors. Regulatory uncertainty, high sustainability costs, and lacking knowledge or the lack of employee training were identified as the most significant factors. Farooque et al. [47] also identified 13 barriers in four main categories in the adoption of blockchain-based life cycle assessment (LCA). The results based on the fuzzy DEMATEL method are listed in Table 1.

On the other hand, Saberi et al. [48] also classified the barriers of BC adoption in the supply chain into four main categories with the sub-categories that were derived from the literature and are listed in Table 1. The developed model was based on the following elements:

- Intra-organizational barriers: identifying the internal activities of the company.
- Inter-organizational: stemming from relationships of the organizations and their network partners.
- System-related: stemming from the technology (BC) itself.

- External barriers: stemming from the outside of the organization by other influenced stakeholders such as legal entities, society, and the environment.

In this field, another comprehensive model was also conducted based on the integration of the information system success (ISS), TTF, and UTAUT by Alazab et al. [49]. Variables such as performance expectancy, facilitating conditions as discussed before [35], and also considered trust factors as technology trust and inter-organizational trust were used. The important results and the list of variables are summarized in Table 1.

Additionally, some researchers have employed new frameworks to study the impact of their utilized factors in BC adoption. One of these methods used in the supply chain area was cross-impact matrix multiplication applied to classification (MICMAC) and interpretive structural modeling (ISM) implemented by Balki and Surucu-Balci [50]. Eight factors in BC adoption were investigated such as perceived resource, the adoption resistance of some stakeholders, initial capital requirement, and the concerns stemming from privacy or business information sharing in BC frameworks that were four critical factors. Other factors are listed in Table 1. The most significant factors as the result of their study were also found. On the other hand, another new approach based on nine factors was developed by Jardim et al. [51]. Using the design science research (DSR) approach, technology, trust, trade, and traceability or transparency were introduced as the most significant factors.

Then, Saurabh and Dey [52] investigated adoption by using a new theoretical framework. Their result showed that all adopted factors in their proposed model that are listed in Table 1 have a significant impact on blockchain adoption. Finally, Ali et al. [53] used a new practical framework using exploratory research and have identified five factors, listed in Table 1, to examine BC acceptance in the supply chain of the halal food. They conducted different case-studies and determined the low, moderate, and high impact of the five variables in each case.

Table 1. Blockchain adoption in supply chain.

Source	Object Studied	Theory	Results	Factors Considered and Descriptions
Kamble et al. [34]	supply chains in India	Integration of TAM, TRI, and TPB	- The impact of discomfort and insecurity on the perceived ease of use and usefulness are not significant. - The effect of attitude perceived usefulness and perceived behavior on behavioral intention. - Negligible impact of subjective norm on behavioral intention.	TAM: perceived usefulness and perceived ease of use TPB: actual use, intention to use, behavioral attitudes, subjective norms, and perceived behavior control TRI: innovativeness, discomfort, insecurity, and optimism
Queiroz and Wamba [35]	Supply chain and logistics in India and US	Altered UTAUT (using TAM and their literature review)	- The positive impact of performance expectancy on behavioral intention as a motive behind blockchain adoption. - Significant effect of facilitating conditions factor just in the US case. - The positive impact of the trust factor impacts only in the Indian context.	TAM, factors from the provided literature, and an altered model with different factors were used including social influence, performance expectancy, facilitating conditions, the transparency of BC, behavioral intention, and trust among the stakeholders.

Wong et al. [36]	Supply chain in Malaysia	UTAUT	- The effect of facilitating condition on the intention of BC adoption. - Insignificant effect of PE, and EE on BI. - The significant impact of RS on FC as a moderator. However, the study could not show the moderating influence of regulatory support on facilitating conditions.	Factors were listed as the following: performance expectancy (PE), trust (T), effort expectancy (EE), facilitating condition (FC), regulatory support (RS), and technology readiness and affinity.
Kouhizadeh et al. [37]	Barriers in supply chain	TOE framework and force field theories	Identifying the significant barriers according to two groups of understudy people: academics and practitioners	Technological: immaturity of the technology, security, accessibility, and negative perception toward technology. Organizational: management commitment, policies, culture, and financial constraints. Inter-organization groups: information disclosure, awareness lacks, and collaboration problems. Environmental: ethical practices, policies of the government, general normative.
Kamble et al. [38]	Supply chain	TAM and TOE	The following factors were identified as the significant drivers: partner readiness, perceived ease of use, competitor pressure, and perceived usefulness.	Traditional TAM factors. TOE factors including three main categories.
Lanzini et al. [39]	Supply chain	A framework based on TOE	Organizational factors are the most significant drivers among three groups of dimensions	Organizational constructs such as people's readiness . Technological constructs such as cost and governance. Environmental constructs such as customers' influence.
Suwanposri et al. [40]	Supply chain in Thailand	A modified TOE	Four new drivers have been identified as the following: ✓ Operational efficiency; ✓ Suitable application; ✓ Supportive governmental policies and regulations; ✓ The stakeholder cooperation. Reporting minor differences between the adoption of BC in supply chain and financial applications.	Technological factors such as data integrity and data security. organizational factors for example organizational readiness and the top management support. Environmental factors such as network effect.

Wamba et al. [41]	Supply chain in US and India	Developed a new conceptual model	The influence of the trading partner pressure and knowledge sharing were recognized as vital on the BC adoption. The blockchain and supply chain transparencies impact the supply chain performance.	The following factors were investigated: knowledge sharing, trading partner relationship, transparency, supply chain performance.
Aslam et al. [42]	Supply chain management in the oil industry	A new conceptual framework	The supply chain management and operational performance are positively connected.	The main factors were listed as the following: ✓ The blockchain factors; ✓ The SCM practices; ✓ The operational performances. The complete list of sub-categories can be found in the literature.
Karuppiah et al. [43]	Supply chain	Decision-aid Model	Forty prominent under six main challenges to blockchain adoption were identified using a model with three steps: fuzzy Delphi technique, Grey-DEMATEL, and WASPAS (weighted aggregated sum product assessment) method. Challenges were ranked based on their importance as the result. The type of the challenges based on the cause-and-effect factors were also identified.	Organizational such as limited technological support, non-existence of collaboration, training facilities absence, time, and opposition by stakeholders. Facial such as cost of high computational and online platform solutions. Technologies such as limited technology access, technical expertise absence, high computerization grade, and management of storage. Privacy and security such as collusion attacks and reputation-based attacks. Regulatory like compliance risk and non-existence of universal regulatory binding. Societal challenges are only the misconceptions about blockchain technology.
Yadav et al. [44]	Agricultural supply chain in India	Identifying factors and modeling them using a combination of ISM and DEMATEL methods	Significant barriers of BC adoption are the Lacks stemming from the following: ✓ Trust among agro-stakeholders; ✓ Government regulation.	Some of the barriers were lack of standardization and interoperability, collaboration for the creation of consortia, suitable government regulation, and regulatory uncertainty, system speed and scalability, trust factor among the stakeholders or the perception of the public, the awareness of the agro-stakeholder and ease of use.
Sunmola et al. [45]	Supply chain	A new model based on a set of factors	Important factors identified are supply chain network, blockchain costs, firm resources, law and governance, and blockchain compatibility.	Eight factors such as digital technology use, disruptions/environmental variables, structural change, security, policy, and laws as negative factors, positive factors, and organizational variables were used based on the literature study results.

Sahebi et al. [46]	Supply chain	A model with several barriers (derived from the literature)	Identifying 14 barriers of the BC acceptance using the literature, then accepting 9 barriers based on the results of the BWM/Fuzzy Delphi method, and finally finding the most important ones.	Fourteen factors: scalability issues, integrating problems, high sustainability costs, lack of standardization, the complexity of establishing, regulatory uncertainty, knowledge or employee training lacks, risks stemming from the market, technology risks, low/no transaction fees, risks of privacy, risk due to the cyber-attacks, and contractual risk, and finally usage in the underground economy.
Farooque et al. [47]	Adoption of blockchain-based LCA	A model based on 13 barriers	Technology immaturity, and technical issues for gathering the supply chain real-time data were recognized as the main cause barriers. Other prominent barriers were listed as the lack of: Government policies and regulation guidance and support as well as new organizational policies.	Thirteen final barriers were divided into four main categories: intra-organizational such as new organizational policies lack, and hesitation to convert to new systems. Inter-organizational such as information disclosure policy challenges in the supply chain and among the partners. System-related such as the immaturity of technology. External barriers, for example, a lack stemming from government policies.
Saberi et al. [48]	Supply chain	A new framework with four main categories	Designing a new framework based on the four main categories and the subcategories derived from the literature.	Intra-organizational: cultural differences, sustainable integration challenges, collaboration challenges, etc. Inter-organizational: financial constraint, lacks knowledge, management commitment, support, etc. System-related: security, access, hesitation to adopt, immutability, immaturity. External: lack of government policy, involvement of external stakeholders, etc.
Alazab et al. [49]	Supply chain	Integration of ISS, TTF, and UTAUT	First, it was identified that the influence of the social influence factor of the UTAUT is not important. In addition, inter-organizational trust has a significant effect.	Some of the main variables were listed as social influence, system quality, quality of information, service quality, blockchain efficiency, the TTF of blockchain, effort expectancy.
Balki and Surucu-Balci [50]	Maritime supply chain	A framework based on 8 barriers and using (ISM) and (MICMAC)	In this study, the lack of influential stakeholders' support, understanding the BC, and governmental regulations were listed as the most significant factors.	Some of the factors were considered as the lack of: trust, early adopters, government regulations, knowledge/understanding about BC, support from influencing stakeholders.

Jardim et al. [51]	Supply chain	The Design Science Research (DSR) approach/an exploratory research	Four perspectives were identified as the main dimensions in the BC adoption including technology, trust, trade, and traceability or transparency.	Nine factors were discovered, including: the trends of the acceptance/adoption verified by the market, trust factor based on the level on the technology and the technology provider, perceived benefits, smart contracts, cost-benefits due to the reduction of inefficiencies, overall benefits, automatization processes, and finally being accepted by other players in the supply chain.
Saurabh and Dey [52]	Agri-food supply chains	Developed a theoretical framework	Important factors were listed as price, dis-intermediation, trust, utilities, compliance, traceability, and coordination and control.	The following factors were analyzed using a conjoint analysis (CA) method: ✓ Traceability; ✓ Disintermediation; ✓ Trust; ✓ Coordination/control; ✓ Compliance factor; ✓ Price of technology.
Ali et al. [53]	Food supply chain	A new practical framework	Important challenges were identified as: ✓ Supply chain integration; ✓ Food regulations.	Five main challenges using an exploratory approach were discovered including: regulatory culpability, complexity, and capability, competitive advantages and cost, external pressure and change management, and halal sustainable production

6. Blockchain Adoption in Industries and Firms

Blockchain adoption in different industries such as aviation, logistics, elderly care, education, etc. was the subject of several works. For this purpose, the authors used different frameworks such as TOE, UTAUT, and TAM. In addition, extended models, the integration of frameworks, and using new conceptual models were considered by some studies as well.

Extended TAM, as discussed in the supply chain, was also utilized here for studying the BC adoption in the aviation industry in Korea. For this purpose, Li et al. [22] used three sub-factors for each of the main categories of the standard TAM (perceived ease of use and perceived usefulness) (Figure 4). They listed the factors with a positive impact on the BC adoption as digitized management, tracking and tracing, the management of air traffic, industry standards and regulatory governance, optimization on efficiency and technological improvements. Additional results are also reported in Table 2.

In another work, Caldarelli et al. [54] studied the BC adoption in Italian firms using the UTAUT framework. They considered four main constructs in their work. Three of four main factors were considered as the study conducted by Queiroz and Wamba [35], but they also used effort expectancy as another factor, which was also used by Alazab et al. [49]; the definition of this item in this study is given in Table 2. They found that, firstly, social influence and performance expectancy strongly influence individuals' intention to apply blockchain; secondly, the results identified that experience has a negative impact on the intention of adopting blockchain technology.

The TOE-based framework was used in the studies on blockchain adoption in industries as well. BC acceptance in the freight logistics industry using the TOE was discussed by Orji et al. [55]. They used different sub-categories for three main constructs including organizational, technological, and environmental. For example, they listed the firm size, top management support, possibility of training facilities, human resources capability and perceived costs of investment, and organizational culture as the organizational sub-categories. Other factors are given in Table 2. However, between those factors, they identified government support and policy, infrastructural facilities, and the availability of specific blockchain tools as the most significant ones. Wong et al. [56] also used a TOE model to study blockchain adoption in small and medium enterprises (SMEs) in Malaysia. The factors considered in their study are listed in Table 2. They provided the significant and insignificant factors in the blockchain adoption as the result. In another different concept, Fernando et al. [Fernando, 2021 #106] focused on examining the drivers of blockchain adoption together with carbon performance. They chose a TOE model and identified technical competency and lack of competitive pressure as the important adoption factors. They also did not find any evidence to show the relationship between early BC adoption and low-carbon performance. The TOE model was also applied by Schmitt et al. [57] to recognize the important factors in the adoption of IoT, blockchain, and smart contracts in the firms. They examined 13 sub-categories as the main factors impacting the adoption, six of which are similar to the traditional TOE introduced by Tornatzky and Fleischer [29].

The other areas that researchers focused on in their works were the studies on the blockchain application in education and healthcare industries to obtain the significant variables in the adoption of this technology. For this, Balasubramanian et al. [58] used a readiness assessment framework to study BC acceptance in healthcare. In this study, individual stakeholder readiness, stakeholder collaboration readiness, and facilitating conditions readiness were considered as the main categories which also include different variables as the sub-categories (which can be found in the literature). They identified trust, infrastructure, privacy, innovation propensity, and regulatory/legal aspects as the key conditions required for widespread blockchain adoption and also highlighted the vital role of governments. Other results are listed in Table 2. Another work by Srivastava et al. [59] also focused on different ethical challenges in BC adoption in E-healthcare. They used several factors (given from their literature) to develop a framework. They used accountability, fairness (treating reasonable/equal to all people in terms of protocols or technology), privacy, accuracy, access to data, data ownership, and governance. They also used the "right to be forgotten" as a challenging factor, which refers to the right to delete irrelevant/no longer relevant or inadequate personal information from the databases. As a result, they identified the former challenge together with accuracy as the most important challenges of BC adoption.

In addition, an integrated model was used to study the intention of using blockchain in higher education by Iftikhar et al. [60]. They integrated TOE and TAM concepts by adding perceived ease of use and perceived usefulness to the technological dimension of TOE together with using relative advantage and scalability concern as the other variables of the context. On the other hand, they also used top management support for organizational dimensions and competitive pressure, and the regulatory policy as the constructs of environmental factors. Competitive pressure was found as the most significant factor, and other results are summarized in Table 2. TAM-based integrated frameworks in this sector were also applied by Ullah et al. [61] to study the adoption of smart learning environments. They designed their integrated model based on TAM and DOI by adding the trialability, relative advantage, and compatibility to the TAM factors. They identified the significant effect of the compatibility factor (defined as how compatible technology is considered with the adopters' current expectations, needs, and beliefs) on blockchain adoption. Other factors also are defined in Table 2.

The higher education sector was the subject of another work by Kumar et al. [62]. They, however, applied an extended TAM framework in the study. They used perceived

security/privacy and trust as the additional variables. The result of this study identified the positive effect of incorporated factors on the adoption intention of the individuals. In addition, the perceived security and privacy factor were found as important factors impacting trust, ease of use, and perceived usefulness. Some of the considered factors in their study were also used in an article with the focus on another application of blockchain technology in gaming by Gao and Li [63]. They used an extended TAM to gain the significant factors of blockchain adoption in this sector. For this purpose, they chose additional factors such as perceived security, trust, privacy, perceived enjoyment, and subjective norms in their model. These subjective norms are defined as "the factors shaped by normative beliefs that the individuals attribute to what a relative other awaits them to do for adopting technology as well as their motivation to comply with those views". On the other hand, the perceived security is bringing events, conditions, or circumstances with the possibility of causing economic hardship to network resources and information in the data modification, destruction, disclosure, and fraud types. Finally, perceived enjoyment identifies how enjoyable a specific activity of technology can be considered (while eliminating other performance consequences stemming from system use). Another extended TAM was also used by Mnif et al. [64] to discuss blockchain adoption in social media. Their results and the factors considered are listed in Table 2.

Blockchain technology can also be applied in smart lockers. A combination of an extended TAM and a TTF model was used by Lian et al. [65] to obtain the important factors of blockchain adoption in this system. They used additional variables including attitude (feeling toward BC) and usage intention (willingness of users) to TAM factors. They also applied TTF factors including individual technology fit (completing the logistic services using blockchain) and task technology fit (dealing with logistics). They, in addition, added the perceived safety and network externality (positive relationship between the number of users and the amount of the technology merits). Their results found perceived usefulness and perceived ease of use as the critical factors. However, the effect of network externality and safety was not identified as the main concerns in their findings.

Using new frameworks with several factors as the barriers and challenges of the adoption and integrated frameworks were the approaches of some other studies in the industry field. For example, Xu et al. [66] used eleven barriers in their model to study adoption in the architecture, engineering, and construction (AEC) industry. Barriers were selected as the variables such as scalability issues (due to the low data transmission speed together with inefficient transactions), lack of interoperability and standardization (stems from facing challenges in the integration of BC and other technologies), lack of knowledge and expertise (especially the challenges of implementation of BC in the early stages), project complexity (due to the temporal nature, uncertainty of construction, and the projects' fragmentation), and industry resistance to change (especially traditional industries). Other factors are described in Table 2. They identified a lack of information technology infrastructure and legal and regulatory uncertainty (as many countries do not yet have the required laws, policies, or supervisions) as the important variables by deriving the power factor for each variable. Another example, the study by Biswas and Gupta [67], was reviewed. They identified the barriers in the industry and service sectors using a literature study as well as the opinion of the experts. They categorized the barriers as 10 main constructs such as risks of technology, privacy, cyber-attacks, and market-based together with different uncertainties due to the legal and regulatory and transaction-level. Other factors were also considered as scalability challenges, high sustainability cost, poor economic behavior in the long run, and usages in the underground economy. They identified the most impactful barriers as the result of their research, which is summarized in Table 2.

Zhou et al. [68] also used the former method based on identifying variables from the literature in the maritime industry. They then conducted different surveys to collect data and analyzed them using an analytic hierarchical process (AHP) together with a PESTEL (political, economic, social, technological, environmental and legal) analysis and fishbone diagram. They used five main dimensions including several factors (Table 2). In this

study, sufficient capital, staff training, ease of local legislation, the shipping community's support, professional assistance and consultation, and senior management support were ranked as the most important critical success factors with 0.25, 0.24, 0.16, 0.15, 0.12, and 0.006 priority factors, respectively. The challenges of implementation of BC were also ranked in the same way, and, for example, implementation cost and a lack of experienced partners were ranked as the two first ones with 0.25 and 0.22 priorities, respectively.

Another work by Pu and Lam [1] focused on a novel conceptual framework, based on the TAM and TOE model, and also added new features in maritime industries. They used five main dimensions including technical features of blockchain, commercial benefits of blockchain to the industry, applicable areas in the maritime domain, major maritime stakeholders involved, and the potential adoption challenges in the industry. However, they also used several sub-categories for each of the main ones (which can be obtained in [1]). They found all technical aspects as the significant basis of the commercial benefits gained by the industry. They also reported the positive relationship between technological factors and commercial benefits (additional results are provided in Table 2). In another similar study, Lu et al. [69] used a combination of DOI and TOE approaches. They applied the factors under three main categories of the TOE. They listed the factors with a positive impact, insignificant factors, and factors with an indirect impact on the BC adoption (as listed in Table 2). They also reported the positive effect of information security and technology trust on the relative advantages of BC, which also showed an indirect impact on the blockchain adoption intention. However, privacy protection is an insignificant factor.

Empirical research was conducted by Lohmer et al. [70] to find the barriers impacting the adoption of BC in operations management and manufacturing within the industry. They used several interviews with the experts and then proposed the findings of their study using the Saberi et al. [48] model, which is based on classifying the barriers into four main categories (discussed before). Their main results are summarized in Table 2.

Table 2. Blockchain adoption in industries.

Source	Object Studied	Theory	Results	Factors Considered and Descriptions
Li et al. [22]	The aviation industry in Korea	Extended TAM	Significant factors were listed. In addition, they found that enhancing the optimization on efficiency and technological improvements as well as regulatory governance and industry standards can positively affect the perceived usefulness in tracking and tracing, air traffic management, and digitized management.	Six factors were considered as the sub-categories of perceived usefulness and perceived ease of use. Factors are shown in Figure 4.
Caldarelli et al. [54]	Italian firms	UTAUT	Firstly, social influence and performance expectancy possess the positive impacts on individuals' intention to apply blockchain. Secondly, the results identified that experience impacts the intention of BC adoption negatively.	Social influence, facilitating conditions, performance expectancy were identified by [35]. Effort expectancy was also listed as the simplicity perception which is expected in the utilizing of the technology.

Orji et al. [55]	Freight logistics industry	Based on TOE	They introduced the list of the most vital factors affecting the BC acceptance as: ✓ Access to the specific BC tools; ✓ Infrastructural facility; ✓ Government support and support.	Organizational. Technological ones were the availability of specific BC tools, complexity, ease of being tried and observed, perceived benefits, infrastructural facility, compatibility, and security and privacy. Environmental variables were government support and policy, competitive pressure, institutional-based trust, market turbulence, and stakeholder's pressure.
Wong et al. [56]	SMEs in Malaysia	TOE Framework	They reported: Significant impact of complexity, competitive pressure, relative, and cost. They also identified the market dynamics, regulatory support, and upper management support as the insignificant drivers.	They considered three dimensions: ✓ Organizational: ✦ Cost together with upper management support. ✓ Environmental: ✦ The regulatory support, competitive pressure, and market dynamics. ✓ Technological: ✦ Relative advantage and complexity.
Fernando et al. [71]	Manufacturing firms	TOE	Identifying technical competency and a lack stemming from the competitors' pressure.	TOE factors were: compatibility, top management support, competitive pressure, the size of the firm, and Technology competence.
Schmitt et al. [57]	IoT, blockchain and smart contracts in firms	Based on the TOE	Thirteen elements by a focus on the three TOE constructs were identified as the main factors. Six of them were matched with the traditional TOE by Tornatzky and Fleischer [29].	Technical (internal and external variables) including performance expectancy, technology maturity, perceived compatibility. Organizational including perceived compatibility, firm size, concerns of the security, organizational slack, and perceived technical capability. Environmental including competitive pressure, regulatory policy, Legal uncertainty, consumer perception, and external data.
Balasubramanian et al. [58]	Healthcare	Readiness assessment framework.	They identified the concerns as the low readiness of businesses (like SMEs) in motivational and engagement factors.	The categories and factors are considered as: Individual, stakeholder readiness such as motivational and engagement readiness, stakeholder collaboration readiness such as government and business, entities facilitating conditions readiness such as privacy and trust.
Srivastava et al. [59]	Healthcare	A framework based on several factors	Most vital factors: ✓ Accuracy; ✓ Right to be forgotten.	The ethical factors were derived from their conducted literature.

Iftikhar et al. [60]	Higher education in Malaysia	An integrated TAM/TOE model	The significant impact of perceived usefulness, top management support, and competitive pressure and opposite impact of perceived ease of use and relative advantage on BC adoption.	Three different categories (with seven factors) were used in the integrated framework: ✓ Technology context; ✓ Organizational context; ✓ Environment context.
Ullah et al. [61]	Education (Smart Learning Environments)	Integration of TAM and DOI	The findings identified the compatibility's significant effect on blockchain use. Blockchain technology also was recognized as a significant factor in BC adoption.	In addition to the factors of TAM: ✓ Trial-ability: to what extent technology can be easily explored by the potential users; ✓ Relative advantage: how much better technologies can be considered compared to the concept that they have substituted; ✓ Compatibility.
Kumar et al. [62]	Higher Education	Extended TAM	The positive effect of incorporated factors on the adoption intention. The significant impact of the perceived security and privacy factor on trust, ease of use, and perceived usefulness.	Additional variables were added to the TAM framework, including: ✓ Perceived security and privacy; ✓ Trust.
Gao and Li [63]	Gaming	Extended TAM	The impact of perceived usefulness on users' behavioral intention to use technology. Insignificant positive impacts of subjective norms on users' behavioral intention to use this technology.	They considered the following aspects in their framework: ✓ Perceived security; ✓ Trust; ✓ Privacy; ✓ Subjective norms; ✓ Perceived enjoyment; ✓ Perceived ease of use and perceived usefulness from the TAM.
Mnif et al. [64]	Social media	Extended TAM	Decentralization characteristics, shareability, as well as security possesses the most impact on the users' intention. The important awareness of blockchain adopters was also concluded.	The main dimensions were: perceived usefulness, social norms, both negative and positive sentiments, and joyfulness and trust.
Lian et al. [65]	Smart lockers	TAM and TTF	Identified perceived usefulness and perceived ease of use as the critical factors. Safety and network externality of smart locker were not considered as main concerns and their effects were insignificant according to their findings.	TAM additional factors: attitude (feeling toward BC) and usage intention (willingness of users) in their model. TTF factors: individual technology fit (completing the logistic services using blockchain) and task technology fit (dealing with logistics). Other factors: perceived safety and network externality

Xu et al. [66]	AEC industry	A new framework including 11 barriers	The following factors were identified: ✓ Lacking information technology infrastructure; ✓ Regulatory and legal uncertainty.	For example, collaboration and network establishment together with security and privacy, lack of IT infrastructure and trust amongst stakeholders, Legal and regulatory uncertainty (as many countries do not have the required laws, policies as well as supervisions yet), and the high cost of the initial investment.
Biswas and Gupta [67]	Industry and services sectors	A new framework with several barriers	The most impactful barriers were market-based risks and challenges in scalability. Also, poor economic behavior and high sustainability costs possess the most impacted barriers during successful BC adoption.	They used the DEMATEL technique to investigate the barriers. Ten main categories were identified for the adoption barriers.
Zhou et al. [68]	Maritime industry in Singapore	A framework based on five main dimensions	Sufficient capital and implementation cost were ranked the first important critical success factors and implementation challenges, respectively.	Six main challenges and thirteen personal concerns in five main dimensions: Methods, people, technology, external environment, and organization.
Pu and Lam [1]	Maritime industry	A novel conceptual framework (based on TAM and TOE model and new features)	The significant impact of stakeholder management. Legal, technological, and operational challenges of BC adoption in the maritime industry. The specific contextualized application fields of BC for each type of commercial benefit.	Five dimensions were used in the framework as the following: technical features of blockchain, commercial benefits of BC to the industry, applicable areas in the maritime domain, major maritime stakeholders involved in these applications, and potential adoption challenges in the industry.
Lu et al. [69]	Elderly care industry.	Integration of the DOI theory and TOE	Positive impacts of top management support, corporate social responsibility, relative advantage, and organizational readiness; and insignificant impact of competitive pressure complexity, and government on blockchain adoption. The indirect impact of government and competitive pressure support factors on promoting blockchain adoption.	The factors considered in this integrated framework were: ✓ Organizational: ▪ Top management support, organizational readiness, corporate social responsibility. ✓ Technological: ▪ Complexity, relation advantage, information security, privacy protection, technology trust. ✓ Environmental: ▪ Government support, privacy protection
Lohmer et al. [70]	Operations management and manufacturing in industries	Proposed their model based on [48]	They reported current barriers/challenges as legal uncertainties, lack of clear governance structures, staff difficulties, missing infrastructure, and standardization.	Based on [48], they categorized the barriers into 4 main types: Intra-organizational barriers Inter-organizational Technology (system) External barriers

7. Blockchain Acceptance in Banking and Financial Institutions

In this category, we focused on papers that studied BC adoption in the financial sector and banking. Modified and integrated models were used in the studies in this section as well. Table 3 summarizes all the studies discussed in this section.

In the first study, the TPB adoption model was used to examine the adoption of BC in the financial sector. This study conducted by Chang et al. [72] identified knowledge-hiding as the most vital issue that can be faced in the adoption and development process. A modified TAM was used for studying the blockchain global banking industry. Generally, Kawasmi et al. [73] introduced three categories of blockchain adoption in banking as supporting, hindering, and circumstantial (sub-categories are discussed in the literature). In this work, adoption variables were also listed in three categories: (1) the external variables included currency stability, interoperability, legislations, and regulations; (2) the internal variables were management factors (security, governance, regulatory compliance, and increased transparency), cost, and infrastructure (stability, energy consumption); (3) the perceived usefulness included improving the Know Your Customer (KNC) process, improved transaction speed, competitive advantage, smart contracts, and enhanced data exploration. They reported that the regulation lacks as an important issue that must be not dismissed; they also highlighted that there is a vital need for the revision of current legislation and regulations.

The integration of TOE, DOI, and NIP models was used for studying the BC adoption in the financial market in Iran by Heidari et al. [74]. In this work, the blockchain acceptance readiness levels were considered based on the TOE model. For this, the three levels of technology readiness, environment readiness, and organization readiness were chosen as the levels forming the blockchain acceptance readiness. The variables creating each level have been obtained based on the DOI theory and National Institutional Perspective (NIP). They also used the BC adoption consequences category including the consequences due to the organizational, strategic, economic, information, and technological factors. They identified enjoyment of required technical needs for utilizing platforms working based on BC, enjoyment of suitable speed of Internet connection, and maturity in applying the Internet as well as Internet-related technologies as the most significant factors. Another important finding was that the community's willingness to adopt BC will not overshadow the markets in the financial sector.

In the next work, Saheb and Mamaghani [75] modified the TOE model to study blockchain adoption in banking. For this purpose, they added four categories listed as a business, strategy, operation, and knowledge management as the organizational values (with 25 variables) to 20 barriers found in three main TOE categories. They introduced the most important business process factors as traceability, transparency, and trustworthiness. They also identified the most critical barriers in the industries as organizational and environmental, lack of understanding by top managers, marketing noise, and finally compliance and regulatory requirements. Khalil et al. [76] also studied the significant factors in the adoption of the financial sector by using a moderated mediated model by adding the bank's performance, digital strategy, and blockchain technology factors to the traditional factors. They found the role of the BC adoption between digital business strategy, business process innovation, and financial performance mediating. In addition, the role of information technology alignment between process innovation and blockchain adoption was recognized as the same. They also obtained the positive relationship between digital business strategy with the financial performance of the firm and business process innovation.

Table 3. Blockchain adoption in financial sector/banking.

Article	Object Studied	Theory	Results	Factors Considered and Descriptions
Chang et al. [72]	Financial services	TPB	Recognizing knowledge-hiding, as the most important issue may prevent the success and more development of BC.	Main TPB factors: Perceived behavioral control, attitudes toward the behavior, and subjective norms.
Kawasmi et al. [73]	Global banking	A new modified TAM	The new model can address TAM limitations which makes it appropriate for examining institutional adoption purposes. Regulation lacks were considered as an important issue that must be not dismissed.	In addition to the TAM factors, in the modified studied model, factors from three categories of adoption factors were considered: ✓ External variables; ✓ Internal variables; ✓ Perceived usefulness.
Heidari et al. [74]	Financial markets in Iran	Integration of TOE, DOI, and NIP models:	The required factors to accept the BC were listed as Banks': Enjoyment of required technical needs for utilizing platforms working based on BC. Enjoyment of suitable speed of Internet connection. Maturity in applying the Internet and its related technologies.	Levels were considered as: ✓ Organizational readiness level; ✓ Environmental readiness; ✓ Technology readiness level; ✓ Blockchain acceptance consequences.
Saheb and Mamaghani [75]	Banking	Extending TOE factors	The most important business processes factors: traceability, transparency, and trustworthiness. The most critical barriers in the industries: marketing noise, compliance and regulatory requirements, environmental and organizational, and lack of understanding by top managers.	Twenty barriers were found in three categories considered as: ✓ Organizational; ✓ Technological; ✓ Environmental. Additionally, four main categories were listed as knowledge management, strategy, business, and operation.
Kalil et al. [76]	Financial sector	A moderated mediated model	The positive relationship among digital both firm financial performance and business process innovation and the strategy of digital business. The mediating impact of blockchain adoption and the alignment of information technology were identified.	The key variables including bank's performance, digital strategy, and blockchain technology were extended to traditional models in the literature.

8. Cryptocurrencies Acceptance Models

This section provides a review of the articles found based on the adoption of cryptocurrencies such as Bitcoin. The results of four different studies are summarized. All the studies in this area applied extended TAM models based on different variables added to the traditional TAM with perceived usefulness and perceived ease-of-use factors. Perceived compatibility, perceived risk, awareness, Bitcoin knowledge, and trustworthiness were among the factors added to these works. A summary of these studies, their methods, and the results gained are provided following:

The first study by Kumpajaya and Dhewanto [77] applied a combination of extended TAM using the innovation diffusion theory (IDT) to examine Bitcoin adoption in Indonesia. They used the TAM basic factors together with applied perceived risk, compatibility, and Bitcoin knowledge in their model. Bitcoin was also the focus of another study by Folkinshteyn and Lennon [78]. They added the perceived risk factors, as the amount of suffering (based on your subjective expectation) when facing a loss when wanting to gain the desired result, to the TAM. This factor included two main categories. First, developers' perceived risk in Bitcoin currency includes a diverse range of risks including risks of business failure, regulatory, security, and code/crypto error. Second, the developers' perceived risks in the Bitcoin blockchain were listed as the risk of business failure, fewer regulatory issues, and less stringent security concerns.

In another article, payment processes using cryptocurrencies in the SMEs in tourism and hospitality industries were studied by Nuryyev et al. [79]. This work was shaped based on enhancing the TAM by integrating internal/external forces overshadowing the acceptable behavior. So, in addition to the TAM main factors, internal factors and the external forces (listed in Table 4) were used in their model. They found that first, the motive behind the adoption of this technology is affected by social influence owner/managers personal properties and strategic orientation. Secondly, the perceived usefulness can be a mediator on the effect of strategic orientation, and social influence was also recognized. Additionally, the impact of self-efficacy on the intention to adopt cryptocurrency payments can be mediated by perceived ease of use. Finally, the moderating impacts of the characteristics of the technology age, and gender on adoption were insignificant. In contrast, the social influence impact on perceived usefulness and the behavioral intention was considered significant.

Shahzad et al. [80], in order to study Bitcoin adoption in China, also used extended TAM terms including the perceived usefulness as a mediator (for studying the role of perceived usefulness as a mediator between perceived intention and perceived ease of use), perceived trustworthiness (for considering the impact of trust by providing positive attitudes among individuals), and awareness (for presenting the information about transformation and using it for different goals in an innovative technology). On the other hand, authors can also use the construct of TAM by adding different external variables (x1, x2, …), as illustrated in Figure 3. For example, an adoption model by Albayati et al. [81] used trust, regulatory support, etc. as external factors to study the adoption of cryptocurrencies for the financial transactions; their results are explained in Table 4.

Table 4. Adoption of cryptocurrencies.

Article	Object Studied	Theory	Results	Factors Considered and Descriptions
Kumpajaya and Dhewanto [77]	Bitcoin adoption in Indonesia	Extending TAM with Innovation diffusion theory (IDT)	Perceived compatibility and Bitcoin knowledge were identified as the impacting factors in the technology adoption.	The factors to identify the adoption rate by users were considered as perceived usefulness, perceived compatibility, perceived ease of use from IDT model, as well as perceived risk and Bitcoin knowledge.

Folkinshteyn and Lennon [78]	Bitcoin	Extended TAM: The perceived risk factor was added to TAM.	Perceived usefulness mainly stems from the characteristics of openness with Bitcoin. This factor also enhances the efficiency of the transaction. But users also can face transaction risks. They recommended the TAM framework as a valuable method for financial sector analysis.	Perceived usefulness, perceived ease of use, and perceived risk. Perceived risk includes: ✓ Perceived risk of the developers in Bitcoin currency; ✓ perceived risk of the developers in the Bitcoin blockchain;
Nuryyev et al. [79]	Cryptocurrency payment	Enhancing the TAM integrating to the additional forces	The impact of social influence owner/managers personal properties and strategic orientation on the BC adoption.	✓ Perceived usefulness; ✓ Perceived ease of use. ✓ Internal: ▪ SMEs' strategic orientation, the characteristics of the owner or manager ✓ External forces: ▪ The characteristics of technology and social influence
Shahzad et al. [80]	cryptocurrencies such as Bitcoin in China	Extended TAM	The impact of awareness and perceived trustworthiness on intention to use. The mediator effect of the perceived usefulness on the relationship between the intention to use and the perceived ease of use.	They considered the following factors in the adoption framework: perceived usefulness, perceived usefulness as a mediator, perceived ease of use, perceived trustworthiness, and awareness.
Albayati et al. [81]	Cryptocurrency for financial transactions	TAM	The powerful constructs of experience and regulatory support encourage users by overshadowing their trust in the BC.	They added the following external factors to the TAM: trust, experience, regulatory support, design, and social influence.

9. Other Articles

The adoption models were discussed in some of the sectors that blockchain technology is applicable in including supply chain, industries, financial, and payments using cryptocurrencies in the previous sub-sections. However, blockchain possesses other diverse applications in other areas ranging from education to gaming and healthcare as well. So, the aim of this sub-section is to discuss the models provided to study blockchain adoption in the areas excluded from the previous sectors. The articles that are not focused on a specific field of study (general) are also included in this section.

The first study in this section was conducted by Clohessy et al. [82] based on an extended TOE model in the industries. They considered two additional factors (individual and task-related considerations) to the main TOE contexts. Individual factors are social influence and hedonistic drives and also topics such as expectations, the perception of privacy, trust, and non-utilitarian motives. Task-related considerations, in their study, were considered as the related factors to the technology novelty and its unclear legal implications. According to their results, perceived benefits, security, and complexity were identified as the most significant technological factors. The most important organizational considerations were listed as top management support and organizational readiness. As the environment important considerations, they identified the regulatory environment

and market dynamics. In addition, trust and privacy were identified as the most significant individual factors. Finally, complexity, costs, and a lack of standards were found as the major task-related ones.

Blockchain adoption was also studied by Wang et al. [83] using a capability maturity model (CMM) for studying the adoption of Bitcoin considering its various applications. They used the network category, information systems, computing methodologies, security, and privacy as the main categories. They considered the network load and reliability in the network category. The information systems were chosen as the upgrading, maintenance, architecture, integration, storage, scalability, and business efficiency factors. Furthermore, the standardization and computational complexity are the factors of the computing methodologies dimension. Finally, security of data and transaction security and privacy factors were also utilized in their model. They reported different results, an important one identified the network loading as the main concern because each transaction is broadcasted over the network. Other findings are listed in Table 5.

In another work, a different approach was reviewed. Liang et al. [84] used an extended fit-viability model using the combination of TTF and UTAUT models with the fit-viability model for obtaining the important variables in blockchain adoption. They integrated those frameworks to gain the vital effect of viability as well as the positive impact of functional and symbolic advantages on the assessment of the managers of TTF on the adoption of blockchain. Toufaily et al. [85] also used a different integrated model, but this time based on key concepts adopted from main innovation acceptance theories (mainly DOI and TOE). They also considered the adoption in the networks presence's effects and considering both uncertainty and isomorphic pressures conditions. They studied the BC adoption in the private/public sectors such as companies and industries, but they also considered start-ups, entrepreneurs, and also end-users and society. By using TOE, they categorized their factors into three main dimensions of the TOE. On the other hand, they studied the ecosystem value creation from blockchain adoption on the discussed sectors with specific factors for each of them. They showed that the technical complexity, relative advantage perception, and the lack of compatibility with existing business models with legacy systems and existing skills are the most important factors.

On the other hand, Flovik et al. [86] used the variables given from their conducted literature review in different surveys to study the adoption of BC. Their results showed that the impact of factors stemming from transformative potential including decentralization and automation of transactions factors were less than infrastructural characteristics such as immutability, transparency, and reliability. The other results and the list of factors are in Table 5. Finally, Janssen et al. [87] divided 26 factors from the literature impacting the BC adoption into three main categories (institutional, market, and technical categories) derived from another adoption study [88]. They also proposed the integration of the process, institutional, market, technology (PIMT) model for BC adoption, which was based on Koppenjan and Groenewegen [88].

Table 5. Blockchain adoption in other articles.

Article	Object Studied	Theory	Results	Factors Considered and Descriptions
Clohessy et al. [82]	General industries	Extended TOE	They identified the most significant factors in all five contexts.	They considered two extra dimensions including: ✓ Individual; ✓ Task-related considerations.

Wang et al. [83]	General	Capability Maturity Model (CMM)	Blockchain technology does not gain an optimum maturity level yet. The maturity level in the information systems category was lower. The maturity level was low-level in most features of the BC in the computing methodologies category. In the privacy and security category, the rating of BC technology was recorded well in this study.	This model includes computing methodologies, information systems, networks, and security and privacy. The factors included are: ✓ Network category; ✓ Information systems; ✓ Computing methodologies; ✓ Security and privacy.
Liang et al. [84]	General	Extended Fit-Viability	Their results were as follows: ✓ The vital effect of viability; ✓ The positive impact of functional and symbolic benefits on managers' assessment of task-technology fit.	The model was derived from the fit-viability together with task-technology fit models and the UTAUT.
Toufaily et al. [85]	BC adoption from multi-stakeholders' perspective	An integrated approach (mainly based on DOI and TOE, and considering specific conditions)	Challenges and barriers in blockchain adoption were investigated. They found the significant factors in blockchain adoption.	Technology characteristics challenge Environmental challenges Organizational challenges They also listed the ecosystem value creation from blockchain adoption factors, and also considered organizations and industries, public sector, start-up, end-users, and society. More information in [85]
Flovik et al. [86]	General (different organizations)	Identifying factors in the literature.	The more important role of infrastructural qualities than the blockchain's transformative potential qualities. Most concerns were identified as scalability and maturity.	Motivating: transactions automation, reliability, decentralization, immutability, transparency. Impeding: cost, interoperability, technical maturity, scalability, and knowledge concern.
Janssen et al. [87]	General	A conceptual framework PIMT	They proposed a framework based on the literature in order to apply it in the BC adoption studies.	Factors are institutional, market, and technical.

10. Discussion

As highlighted before, it is vital to investigate the adoption of new technologies. Nowadays, blockchain technology possesses a significant role in many transactions and processes around the world. This trend is predicted to be continued as well. A forecast reported by Chernov and Chernova [89] shows the positive growth of the blockchain market capacity between 2017 and 2024. This capacity is predicted to reach USD 20,550 million in 2024, although this capacity was just USD 800 million in 2017. So, as a vital step, adoption analysis is important to gain more development of BC, and the studies on the acceptance of this innovation can assist to both hold and enhance its users in forthcoming.

According to the points discussed, the blockchain adoption models used in manifold areas were reviewed and summarized in the previous section. For this purpose, the arti-

cles were chosen based on a systematic literature review using the "ScienceDirect" database. Additional articles were also added using the "Google Scholar" database. Then, 56 articles (whether Scopus indexed or not) were chosen and categorized considering the application of the blockchain in manifold fields of study. The applied models and the results of the studies were reviewed; the main results were summarized in Tables 1–5. According to the results of this study, most of the reviewed articles focused on the application of the blockchain in different industry fields and supply chain areas (Figure 5). Additionally, the maximum number of articles was reached in 2021 and 2020 years with 27 and 18 articles, respectively (Figure 6). The BC adoption was also studied in a diverse range of industries such as healthcare, aviation, logistics, etc. The list of industries and the frequency of reviewed articles in this study are provided in Figure 7.

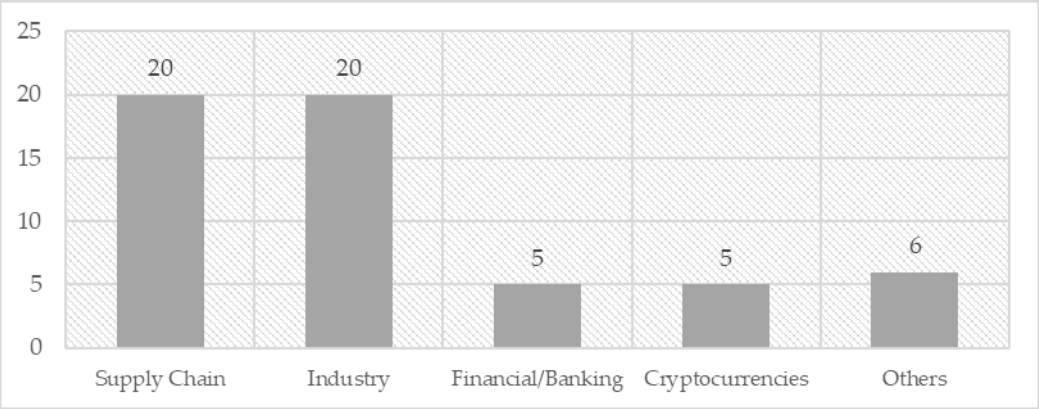

Figure 5. Number of articles reviewed in different areas.

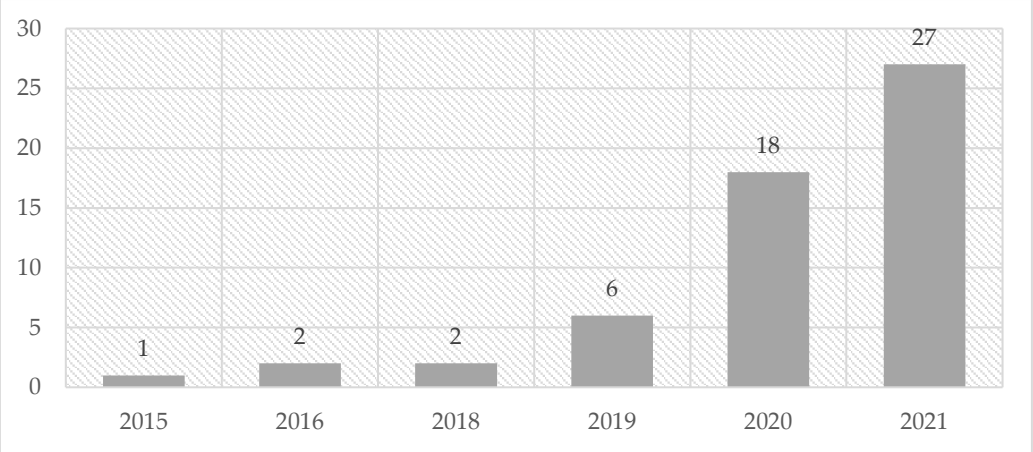

Figure 6. The number of articles reviewed based on the published years.

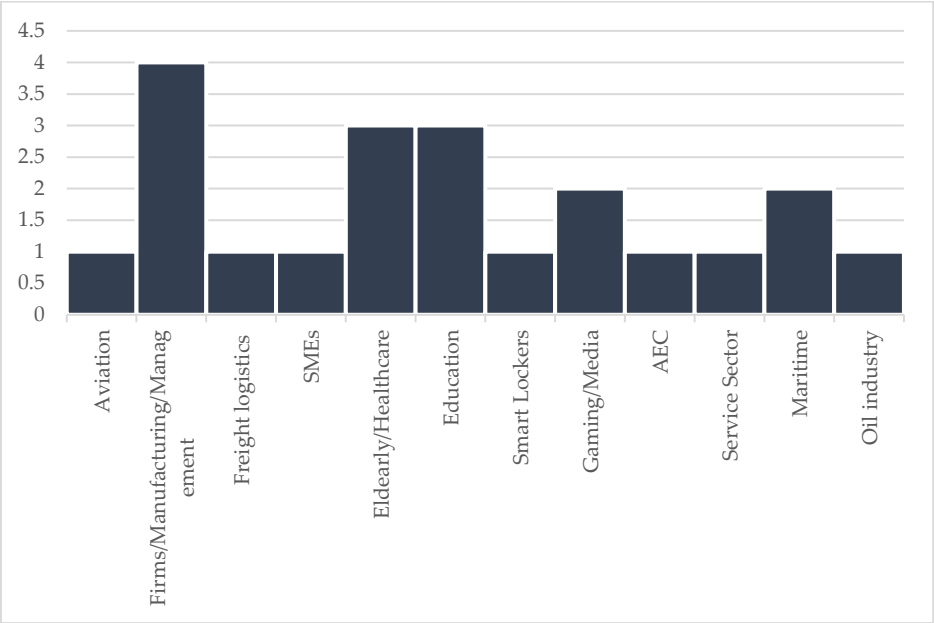

Figure 7. Types of the industries that are reviewed in the paper.

In addition, manifold models were utilized to investigate the acceptance of blockchain technology considering a diverse range of variables in each model. The findings show that 30% of the articles studied in this paper included the technology adoption model. This model was applied as a single method (traditional and extended forms) or integrated with other frameworks such as TOE, TPB, and TRI models (Figure 8).

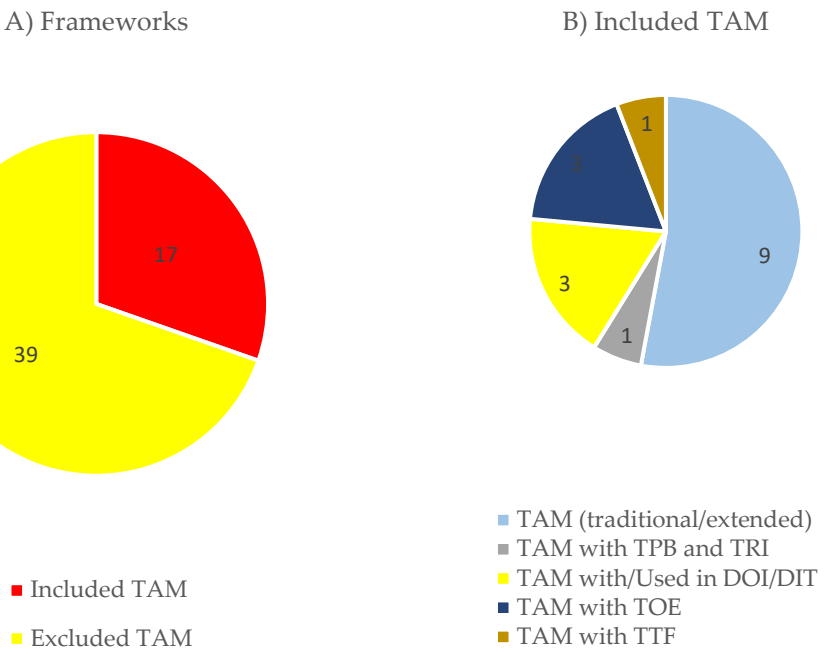

Figure 8. TAM models reviewed in this paper. (**A**) The percentages of articles with/without using TAM. (**B**) The variety of models that included TAM.

The TOE model was another applicable framework in the blockchain adoption studies in 15 articles. As with TAM, this framework was also used as a single method or integrated with other models. Extended TOE frameworks were the focus of several studies as

well. The majority of these studies used extended TOE models by adding new factors to the main constructs of the TOE and the other ones used the TOE framework with DOI and TAM (Figure 9).

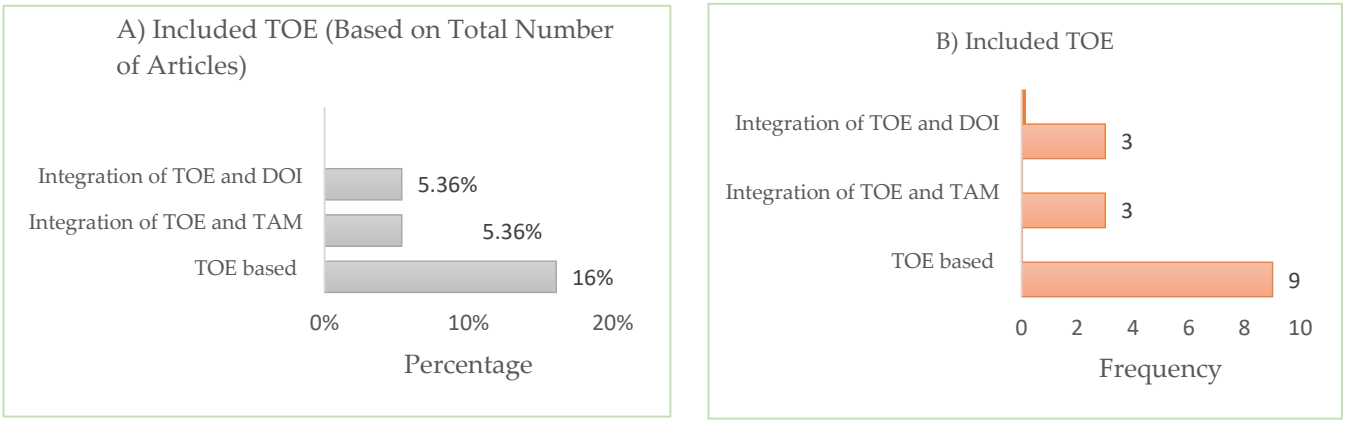

Figure 9. (**A**) Percentage of different TOE models. (**B**) Frequency of using different types of TOE frameworks in the articles reviewed in this study.

Between the main and more common frameworks reviewed in this paper, UTAUT was another model considered by authors to study blockchain adoption. This framework was applied in five different articles as a single/extended/altered method (in three studies) and integrated with other methods (fit-viability/TTF/UTAUT, ISS/TTF/UTAUT).

The main focus of the articles which are reviewed in this study was also based on the new conceptual/theoretical frameworks. For example, Wamba et al. [41], Saurabh and Dey [52], Xu et al. [66], and Aslam et al. [42] developed new frameworks based on the factors/barriers introduced in their studies. Many of these authors conducted literature studies in the first stage to derive the factors/barriers, used surveys to collect the results, and then analyzed them using different methods such as the fuzzy Delphi method. Finally, other studies used less frequent models such as readiness assessment frameworks based on the articles discussed here.

11. Conclusions and Future Work

In this study, the common blockchain acceptance frameworks were briefly introduced. A systematic literature review was then conducted to discuss the articles with focus on blockchain adoption in different areas such as supply chain, different industries, financial sector, etc.

The applied frameworks and the results were reviewed and summarized in the selected articles. The results show that TAM, TOE, DOI, and UTAUT were used frequently in most of the studies. Moreover, many researchers have employed extended TAM/TOE frameworks by adding new variables or a combination of different frameworks instead of the single and traditional models. New conceptual or theoretical frameworks were also the main focus area of many researchers. In these studies, authors have determined a list of factors to consider in their adoption models and analyzed the collected results to obtain the most significant factors among them.

A list of the models used to assess the adoption of BC and their associated factors and components was reviewed in this article. Furthermore, different fields in which BC acceptance has been evaluated were reviewed, although there are some sectors and main applications that are not considered in the adoption studies. For example, industrial IoT (IIoT) can be considered as one of the significant fields. A study by Latif et al. [90] showed that BC can benefit IIoT in many aspects. Another study by Latif et al. [91] also focused on BC application in IIoT as an important technology that can enhance security and trust in

the system. Blockchain application in smart grids in order to improve the security is investigated in different studies as well [92,93]. They aimed to study the applicability of blockchain in the management of smart grids and achieving more secure processes in this area, which could be possible by, for example, assisting users to gain a real-time monitoring. Thus, future studies may utilize the results of this work to gain a new comprehensive framework that is applicable to investigate blockchain adoption in manifold fields. According to the results of the analysis, some factors have not been included in developed blockchain acceptance models, such as security, privacy, and service quality. It is suggested to assess the influence of these factors on blockchain adoption for future study; however, there is a lack of a comprehensive blockchain technology acceptance model.

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